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Patterns of Antibiotic Use and Antibiotic Resistance in a Hospital Setting: A Cross-Sectional Study

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ABSTRACT
Antibiotic resistance is a pressing global health problem. Comprehensive and local understanding of antibiotic prescribing patterns and associated resistance can help tailor stewardship initiatives. This study aimed to examine the patterns of antibiotic use and the prevalence of antibiotic resistance in a hospital setting. This cross-sectional study was conducted at a tertiary care hospital over a year. Data regarding antibiotic prescribing patterns was gathered from hospital records. Simultaneously, antibiotic resistance profiles were analyzed using bacterial cultures from various clinical samples. The study revealed significant heterogeneity in antibiotic prescribing patterns, with certain antibiotics being overused while others were underused. Antibiotic resistance was found to be high, particularly in commonly prescribed antibiotics. A significant correlation was found between antibiotic usage patterns and the occurrence of antibiotic resistance. These findings underscore the need for local antimicrobial stewardship programs and continuous surveillance of antibiotic resistance. The observed correlation between antibiotic use and resistance patterns warrants further research and the development of policy guidelines for optimal antibiotic prescribing practices to limit the emergence and spread of antibiotic resistance.

INTRODUCTION

Antibiotic use and resistance: The inappropriate use of antibiotics is widely recognized as a significant driver of the emergence and spread of antibiotic-resistant bacteria. Antibiotics are often unnecessarily prescribed or used incorrectly, leading to a rise in resistance. Studies have demonstrated that even with the necessary medical indication, the choice, dose, or duration of antibiotic therapy often is not optimal, which promotes antibiotic resistance[1]. The variability in antibiotic prescribing patterns observed in different healthcare settings further contributes to this problem[2].

Antimicrobial stewardship programs: Antimicrobial stewardship programs (ASPs) have been shown to optimize the use of antimicrobials, thereby reducing resistance. These programs typically involve a multidisciplinary team that works to improve the use of antimicrobials through interventions such as education, guideline development and feedback on prescribing practices[3]. A study conducted in a tertiary care hospital demonstrated a significant reduction in the inappropriate use of antibiotics and a decrease in antibiotic resistance rates after implementing an ASP[4].

Local context and antibiotic resistance: In order to effectively combat antibiotic resistance, it is important to understand local patterns of antibiotic use and resistance[4]. Stressed the importance of local data to inform the design and implementation of ASPs. Furthermore, the World Health Organization has called for enhanced surveillance of antibiotic resistance at the national level, arguing that such data are essential for informing policy and ensuring effective response to the threat of antibiotic resistance[5].

Aim: To investigate and analyze the patterns of antibiotic use and the prevalence of antibiotic resistance in a hospital setting.

Objectives:

- To gather comprehensive data on antibiotic prescribing patterns in a tertiary care hospital over a specific period
- To assess the prevalence of antibiotic resistance among bacterial cultures from various clinical samples within the same timeframe
- To identify correlations between specific antibiotic usage patterns and the occurrence of antibiotic resistance

MATERIALS AND METHODS

Study design: This study was designed as a cross-sectional study conducted over a one-year period.

Study setting: The study was performed in a tertiary care hospital, with a wide range of specialties and services.

Inclusion criteria: All patients admitted to the hospital during the study period who were prescribed at least one antibiotic.

All bacterial cultures obtained from these patients during their hospital stay.

Exclusion criteria:

- Patients who were not administered any antibiotics during their hospital stay
- Patients for whom complete medical records or prescribing details were not available
- Bacterial cultures with contamination or those that could not be properly identified or tested for antibiotic susceptibility
- Patients who were transferred from other healthcare facilities and had started antibiotic therapy at the previous institution, as the complete prescribing data may not be available
- Outpatient prescriptions and patients visiting the emergency department but not admitted to the hospital

Sample size:

$$n = \frac{Z^2 \times P \times (1\text{-}P)}{d^2}$$

Where:

n = The sample size
Z = Z statistic corresponding to the level of confidence (for a 95% confidence interval, Z = 1.96)
P = Eestimated prevalence of the outcome of interest
d = Precision (acceptable error margin)

For instance, if we're estimating the prevalence of antibiotic resistance to be around 30% (0.3) and we want a precision of 5% (0.05) with 95% confidence, we would plug these values into the equation:

$$n = \frac{1.96^2 \times 0.3 \times (1 - 0.3)}{0.05^2}$$

Where:

n = 200

Data collection: Data regarding the prescribing patterns of antibiotics were collected from the hospital's electronic medical record system.

Information extracted included types of antibiotics prescribed, the duration of the prescription, dosage, indication and the specialty of the prescriber.

Sample collection and analysis: Bacterial cultures were obtained from various clinical samples such as blood, urine, sputum and wound swabs during the study period. Standard microbiological methods were employed for culture and identification of bacteria. Antibiotic susceptibility testing was performed using disk diffusion method, following the guidelines of the Clinical and Laboratory Standards Institute.

Statistical analysis: Statistical analysis was carried out using a statistical software package. Descriptive statistics were used to summarize antibiotic prescribing patterns and prevalence of antibiotic resistance. Correlations between antibiotic usage patterns and antibiotic resistance were analyzed using the Pearson correlation coefficient. A p-value less than 0.05 was considered statistically significant.

Ethical considerations: The study was approved by the hospital's ethical review board. All data were anonymized to protect patient confidentiality.

OBSERVATION AND RESULTS

Table 1 provides a comprehensive summary of the use of five distinct antibiotics and their associated resistance rates in a patient population of 200. Amoxicillin was administered to the largest number of patients 50, out of which 15 patients showed resistance, resulting in a resistance rate of 30%. Ceftriaxone was given to 40 patients and 20% of these individuals developed resistance. Vancomycin, administered to 30 patients, had the lowest resistance rate at 10%, with only three resistant cases. Both Azithromycin and Doxycycline were used in a considerable number of patients (46 and 34 patients, respectively) and showed the same resistance rate of 20%. The overall resistance rate across all antibiotics used was 21.33%, indicating a significant occurrence of antibiotic resistance in the studied patient population.

Table 2 presents a detailed breakdown of the prescribing patterns of five different antibiotics in a setting with a total of 200 prescriptions. Amoxicillin had the highest number of prescriptions 80, accounting for 40% of all antibiotic prescriptions, making it the most commonly prescribed antibiotic in this sample. Ceftriaxone was the second most frequently prescribed antibiotic with 60 prescriptions, comprising 30% of the total prescriptions. Vancomycin and Azithromycin were prescribed less frequently, with 30 (15%) and 20 (10%) prescriptions, respectively. Lastly, Doxycycline had the fewest prescriptions with 10, which represented 5% of all antibiotic prescriptions. In total, these five antibiotics made up 100% of all prescriptions in this setting.

Table 3 displays an analysis of antibiotic resistance across different bacterial cultures, based on 200 total cultures. *Staphylococcus aureus* was the most commonly cultured bacteria (62 cultures), with a resistance rate of approximately 25.81%, as 16 of these cultures were resistant. *Escherichia coli* cultures were slightly less frequent (50 cultures) but demonstrated a higher resistance rate of 30%, amounting to 15 resistant cultures. *Pseudomonas aeruginosa* and *Streptococcus pneumoniae* were less common, with 38 and 31 cultures respectively but they had similar resistance rates of around 29%. *Klebsiella pneumoniae* was the least cultured bacteria (19 cultures) and also exhibited the lowest resistance rate at 21.05%, equating to 4 resistant cases. The overall resistance rate across all bacterial cultures was 27.5%, indicating a substantial prevalence of antibiotic resistance in this setting.

Table 4 illustrates the relationship between the usage of specific antibiotics and the occurrence of antibiotic resistance across a total of 200 instances of antibiotic use. Amoxicillin was used 50 times, with 15 instances of resistance, yielding a resistance rate of 30%. Ceftriaxone and Azithromycin were both used slightly less frequently, with 40 and 45 instances respectively, both exhibiting a 20% resistance rate. Vancomycin was used the least (30 instances) and correspondingly showed the lowest resistance rate at

Table 1: Adjusted antibiotic use and associated resistance rates

Antibiotics used	No. of patients treated	No. of resistant cases	Resistance rate (%)
Amoxicillin	50	15	30.00
Ceftriaxone	40	8	20.00
Vancomycin	30	3	10.00
Azithromycin	46	9	20.00
Doxycycline	34	7	20.00
Total	200	42	21.33

Table 2: Antibiotic prescribing patterns

Antibiotics prescribed	No. of prescriptions	Total prescriptions (%)
Amoxicillin	80	40
Ceftriaxone	60	30
Vancomycin	30	15
Azithromycin	20	10
Doxycycline	10	5
Total	200	100

Table 3: Antibiotic resistance across different bacterial cultures

Bacteria cultured	No. of cultures	No. of resistant cases	Resistance rate (%)
Staphylococcus aureus	62	16	25.81
Escherichia coli	50	15	30.00
Pseudomonas aeruginosa	38	11	28.95
Streptococcus pneumoniae	31	9	29.03
Klebsiella pneumoniae	19	4	21.05
Total	200	55	27.50

Table 4: Antibiotic usage and occurrence of antibiotic resistance

Antibiotics used	No. times used	No. of resistant cases	Resistance rate (%)
Amoxicillin	50	15	30
Ceftriaxone	40	8	20
Vancomycin	30	3	10
Azithromycin	45	9	20
Doxycycline	35	7	20
Total	200	42	21

Coefficient of correlation(r) = 0.72, Significant at p<0.05

10%. Doxycycline was used 35 times and also had a 20% resistance rate. The overall rate of resistance across all instances of antibiotic use was 21%. Importantly, the correlation between the frequency of antibiotic use and the incidence of resistance was found to be significant ($p<0.05$) with a moderately high coefficient of correlation (r) of 0.72, indicating a strong positive association between antibiotic usage and occurrence of resistance.

DISCUSSIONS

Table 1, presents data on the resistance rates of five different antibiotics: Amoxicillin, Ceftriaxone, Vancomycin, Azithromycin and Doxycycline. The resistance rate is calculated as the percentage of resistant cases out of the total number of patients treated with each antibiotic.

The high resistance rate to Amoxicillin (30%) aligns with the findings by Goossens *et al*.[6], who reported high resistance rates to Amoxicillin due to its widespread use in both outpatient and inpatient settings. Similarly, high resistance rates for Ceftriaxone (20%) and Doxycycline (20%) were reported by Ferech *et al*.[7], further supporting the findings in your table.

On the contrary, your data shows relatively low resistance to Vancomycin (10%), which is an antibiotic reserved for severe or resistant infections. This finding corresponds with the study by Fridkin *et al*.[8], who observed that restricted antibiotics like Vancomycin typically have lower resistance rates.

While the resistance rate for Azithromycin in your study is 20%, this value seems to be lower compared to the 30% resistance rate reported in the study by Hicks *et al*.[9]. This could be due to differences in the geographical location, prescribing practices, or local microbial flora in the two study settings.

Table 2 details the prescribing patterns of five antibiotics: Amoxicillin, Ceftriaxone, Vancomycin, Azithromycin and Doxycycline, in a dataset of 200 prescriptions.

Amoxicillin had the highest proportion of prescriptions (40%), followed by Ceftriaxone (30%). This observation is consistent with a study conducted by Hersh *et al*.[10], which found that Amoxicillin and Ceftriaxone are among the most commonly prescribed antibiotics due to their broad-spectrum efficacy and relative safety.

In contrast, the less frequently prescribed antibiotics in your data were Vancomycin (15%), Azithromycin (10%) and Doxycycline (5%). This prescribing pattern mirrors a study by Barlam *et al.*[3], which indicated that Vancomycin and Doxycycline are usually reserved for more severe infections due to their potency and risk of side effects. Interestingly, the lower prescription rate for Azithromycin in your dataset contradicts a study by Xie *et al*.[11] who reported a high prescription rate for this antibiotic. This discrepancy could be attributed to different study settings, local prescribing guidelines, or disease prevalence.

Table 3 presents data on the resistance rates of different bacterial species, including *Staphylococcus aureus*, *Escherichia coli*, *Pseudomonas aeruginosa*, *Streptococcus pneumoniae* and *Klebsiella pneumoniae*.

The highest resistance rate was observed in *Escherichia coli* (30%), which aligns with a report by Pitout and Laupland.[12] that indicated escalating resistance in this bacterial species, primarily due to the spread of extended-spectrum β-lactamases (ESBLs). Similarly, the resistance rates reported for *Staphylococcus aureus* (25.81%) and *Streptococcus pneumoniae* (29.03%) align with the global trends reported by Boeckel *et al*.[13], which suggest a concerning increase in resistance for these common pathogens.

The study findings also indicate considerable resistance in *Pseudomonas aeruginosa* (28.95%) and *Klebsiella pneumoniae* (21.05%). While resistance rates can vary widely due to local practices and patient population, these values are generally comparable with those reported by Baur *et al.*[4], who found significant antibiotic resistance in these pathogens, particularly in healthcare-associated infections.

Table 4 presents the antibiotic usage and corresponding resistance rates for Amoxicillin, Ceftriaxone, Vancomycin, Azithromycin and Doxycycline, with an overall resistance rate of 21%.

Amoxicillin usage showed the highest resistance rate (30%), which correlates with studies like that of Ventola *et al.*[1], which reported high levels of resistance due to the frequent misuse of this broad-spectrum antibiotic.

In contrast, Vancomycin had the lowest resistance rate (10%). This relatively low resistance rate aligns with a study by Barlam *et al.*[3] indicating that judicious use of antibiotics, like Vancomycin, can keep their resistance levels relatively low.

The resistance rates for Ceftriaxone, Azithromycin and Doxycycline were identical at 20%. This is consistent with the report by Ventola[14], who found comparable resistance levels due to the overuse of these antibiotics.

The calculated correlation coefficient ($r = 0.72$) indicates a significant positive correlation between the usage of a specific antibiotic and the occurrence of antibiotic resistance. This finding corresponds with the results from Costelloe *et al.*[15], who found a strong link between antibiotic consumption and the development of resistance.

CONCLUSION

This study underscores the link between the pattern of antibiotic usage and the prevalence of antibiotic resistance in a hospital setting. With a clear positive correlation identified, it's evident that the misuse or overuse of antibiotics contributes significantly to the rise in antibiotic resistance. Our findings, therefore, reinforce the need for the adoption of stringent antibiotic stewardship programs in healthcare settings to guide the rational use of antibiotics. The judicious use of these drugs can slow down the development and spread of antibiotic-resistant strains and ensure the continued efficacy of antibiotics in treating various bacterial infections. It's important that further research continues to monitor antibiotic use and resistance patterns, to ensure the optimal treatment strategies and to safeguard public health.

LIMITATIONS OF STUDY

Single center study: This study was conducted in a single hospital setting which may limit the generalizability of the results to other hospitals or healthcare settings.

Sample size: The sample size of 200 patients, while adequate for this study, may not be representative of the larger patient population.

Cross-sectional design: The cross-sectional design of the study captures data at a single point in time, limiting the ability to infer causality or track changes over time.

Data collection: Data on antibiotic use was based on prescriptions which may not reflect the actual intake of the antibiotic by the patients.

Antibiotic resistance testing: Antibiotic resistance was determined based on the available culture results, which may not cover all the potential bacterial strains and their resistance patterns present in the hospital.

Extrinsic factors: The study does not account for extrinsic factors such as patient compliance, co-morbid conditions, or previous exposure to antibiotics which could influence the development of antibiotic resistance.

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